



Disaster Resilience of Buildings, Infrastructure, and Communities

US-Japan Panel on Wind and Seismic Effects

February 20, 2013

Stephen A. Cauffman
Acting Chief, Materials and Structural Systems
Division, NIST

Background

- Natural and technological disasters cause an estimated \$57B in average annual costs (and growing), with catastrophes like Hurricane Katrina and future “Kobe” earthquakes causing mega-losses exceeding \$100B.
- Existing extreme load-related prescriptive requirements of building codes, standards, and practices stifle design and construction innovation and increase construction costs by an estimated \$50B-\$100B per year.

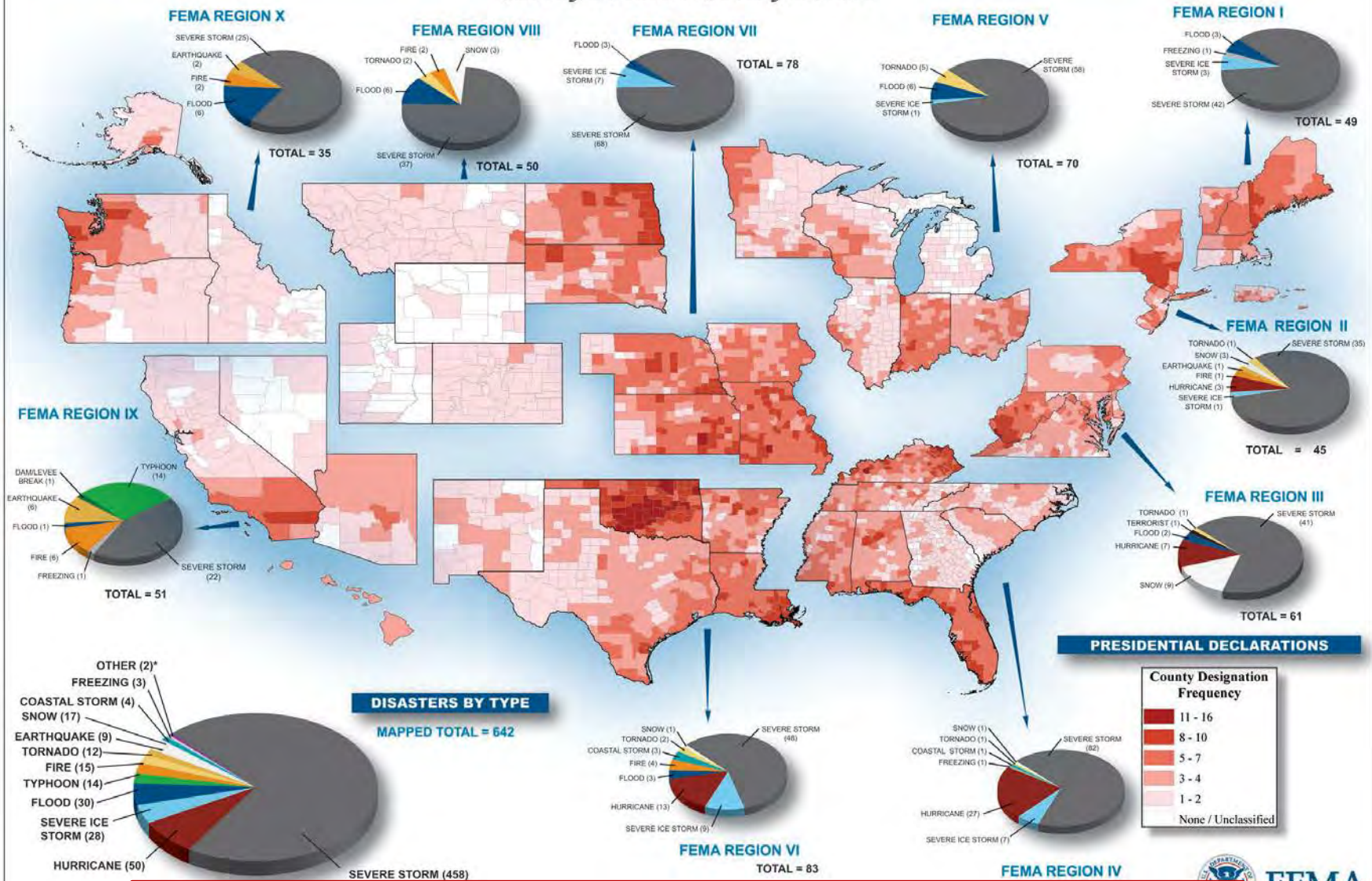


- The built environment repeatedly fails during hazard events.
- Performance of the built environment is dependent the codes and standards in place at the time of construction, enforcement, maintenance, and operation.
- The built environment is highly interconnected; current codes and standards are generally independent and do not account for this interconnectedness.



PRESIDENTIAL DISASTER DECLARATIONS

January 10, 2000 to January 28, 2011



* Other Includes: Dam/Leeve

45 to 81 Presidential Disaster Declarations are made every year

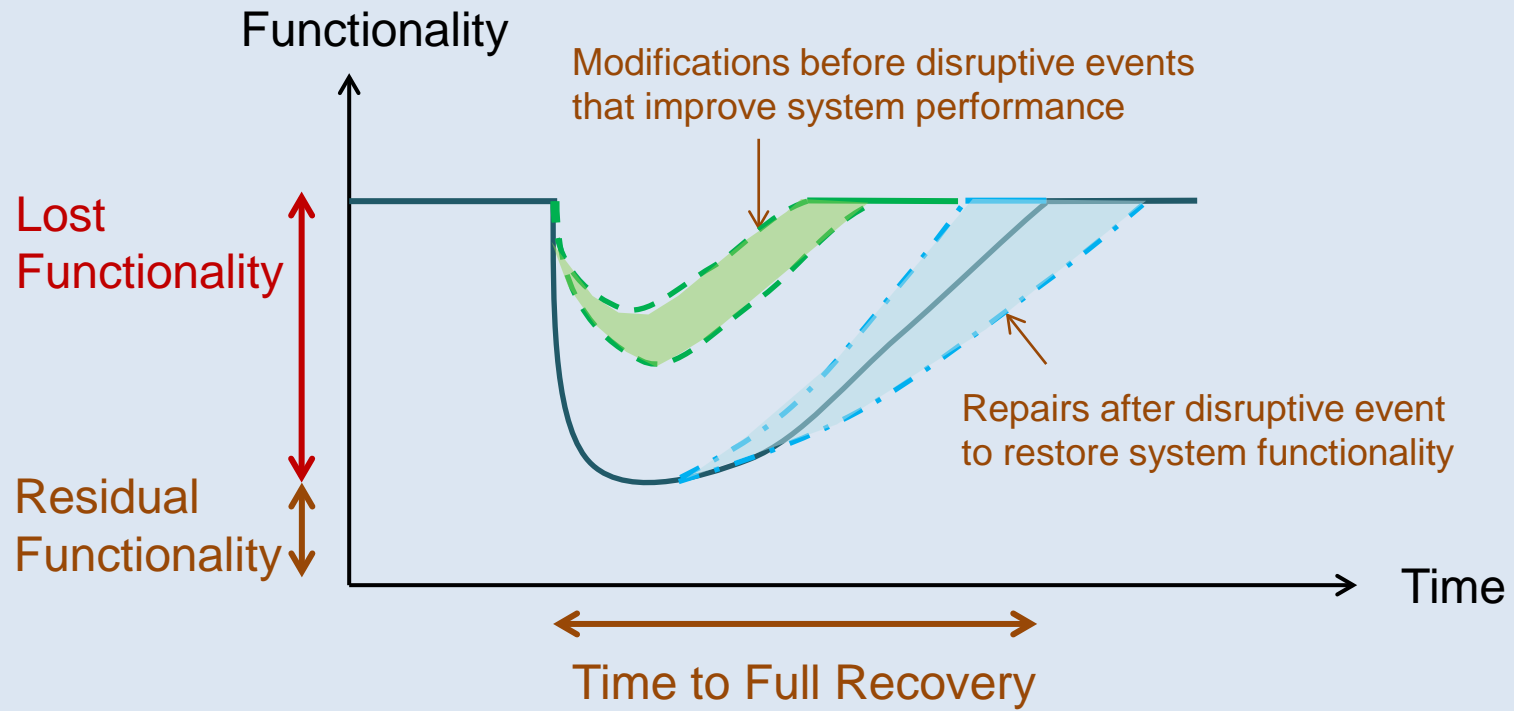


FEMA

Resilience Concepts

Resilience is the capability of a system to

- maintain acceptable levels of functionality during and after disruptive events
- to recover full functionality within a specified period of time



Adapted from McDaniels, 2008 and Bruneau, 2003



Defining the Built Environment

- Buildings (engineered and non-engineered)
 - All systems necessary for intended function
 - Architectural, structural, life safety, mechanical, electrical, plumbing, security, communication and IT systems
- Infrastructure or lifelines
 - Transportation - roads, bridges, tunnels, ports, rail
 - Utility plants and distribution systems - electric power, water and wastewater, fuels, communication



Community Resilience

- Identify multiple hazard and performance levels
 - *What* are the hazards that are likely to affect a community?
 - *What* is the desired performance *of the community* given different hazards levels?
- Consider the function of buildings and infrastructure systems within the context of response and recovery.
 - *What* is the required function of the building or infrastructure system?
 - *When* is the building or infrastructure system required to be restored to functionality to support response and recovery?



Common Terminology/Definitions

- Hazard levels
 - Routine (serviceability)
 - Expected (used in design and to evaluate resilience)
 - Extreme (used in emergency response planning)
- Performance levels
 - Account for function of building or infrastructure system within the context of the community
 - Consider time to return to functionality



What is Needed to Achieve Resilient Communities?

Status Quo

- Prescriptive codes and standards for life safety
- Poor building and infrastructure resilience performance during hazard events
- Emergency response planning but little community resilience planning
- Reliance upon federal disaster funding for recovery



Moving Forward

- Risk consistent, performance based codes and standards for resilience
- Comprehensive approach to design guidance for built environment
- Proactive planning by communities to achieve resilience
- Reduced emergency response and recovery costs



Performance Goals for the “Expected” Earthquake

Phase	Time Frame	Condition of the built environment
I	1 to 7 days	Initial response and staging for reconstruction
II	7 to 60 days	Workforce housing restored – ongoing social needs met
III	2 to 36 months	Long term reconstruction



Transparent Performance Measures for Buildings

Category	Performance Standard
Category A	Safe and operational: Essential facilities such as hospitals and emergency operations centers
Category B	Safe and usable during repair: “shelter-in-place” residential buildings and buildings needed for emergency operations
Category C	Safe and usable after repair: current minimum design standard for new, non-essential buildings
Category D	Safe but not repairable: below current standards for new buildings, often used for voluntary retrofit
Category E	Unsafe – partial or complete collapse: damage that will lead to casualties in the event of the “expected” earthquake - the killer buildings



Transparent Performance Measures for Lifelines

Category	Performance Standard
----------	----------------------

Category I	Resume 100% service within 4 hours
------------	------------------------------------

Category II	Resume 90% service within 72 hours 95% within 30 days 100% within 4 months
-------------	--

Category III	Resume 90% service within 72 hours 95% within 30 days 100% within 3 years
--------------	---



Target States of Recovery for San Francisco's Building & Infrastructure

Phase	Time Frame	Focus of Attention
I	1 to 7 days reconstruction	Initial response and staging for

*EOC's,
City Buildings,
Hospitals,
Police and Fire Stations,
Shelters*



San Francisco General Hospital

Building Category A: "Safe and Operational"

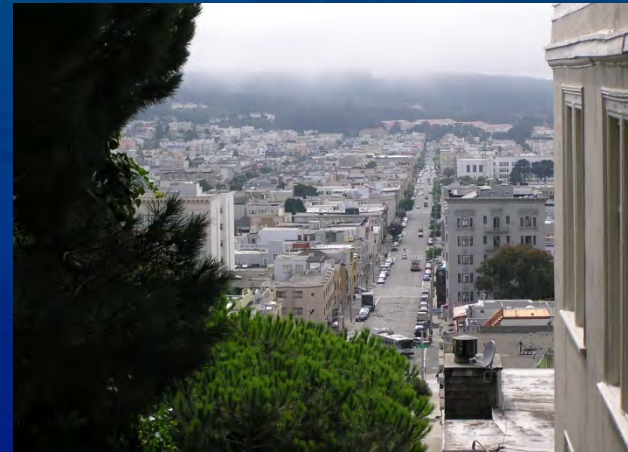
Life Line Category I: "Resume essential service in 4 hours"



Target States of Recovery for San Francisco's Building & Infrastructure

Phase	Time Frame	Focus of Attention
II	7 to 30 days	Workforce housing restored – ongoing social needs met

*Residential structures,
Schools,
Community retail centers,
Doctors offices*



Building Category B: "Safe and usable while being repaired"

Life Line Category II: "Resume 100% workforce service within 4 months"



Target States of Recovery for San Francisco's Building & Infrastructure

Phase	Time Frame	Focus of Attention
III	2to 36 months	Long term reconstruction

Industrial Buildings

Commercial buildings

Historic buildings



Building Category C: "Safe and usable after repair"

Life Line Category III: "Resume 100% commercial service within 36 months"



Target States of Recovery for San Francisco's Building & Infrastructure

TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE

INFRASTRUCTURE CLUSTER FACILITIES	Event occurs	Phase 1 Hours			Phase 2 Days		Phase 3 Months		
		4	24	72	30	60	4	36	36+
CRITICAL RESPONSE FACILITIES AND SUPPORT SYSTEMS									
Hospitals								X	
Police and fire stations			X						
Emergency Operations Center	X								
Related utilities						X			
Roads and ports for emergency				X					
CalTrain for emergency traffic					X				
Airport for emergency traffic				X					
EMERGENCY HOUSING AND SUPPORT SYSTEMS									
95% residence shelter-in-place								X	
Emergency responder housing				X					
Public shelters							X		
90% related utilities								X	
90% roads, port facilities and public transit							X		
90% Muni and BART capacity						X			

Phase I

TARGET STATES OF RECOVERY

Performance measure	Description of usability after expected event
	BUILDINGS LIFELINES
	Category A: Safe and operational
	Category B: 100% restored Safe and usable in 4 hours during repairs
	Category C: 100% restored Safe and usable in 4 months after moderate repairs
	Category D: 100% restored Safe and usable in 3 years after major repairs
	Expected current status

Note: Categories A–D are defined on page 10.



Target States of Recovery for San Francisco's Building & Infrastructure

Phase II

TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE									
INFRASTRUCTURE CLUSTER FACILITIES	Event occurs	Phase 1 Hours			Phase 2 Days		Phase 3 Months		
		4	24	72	30	60	4	36	36+
HOUSING AND NEIGHBORHOOD INFRASTRUCTURE									
Essential city service facilities							×		
Schools							×		
Medical provider offices								×	
90% neighborhood retail services									×
95% of all utilities								×	
90% roads and highways						×			
90% transit						×			
90% railroads							×		
Airport for commercial traffic					×				
95% transit							×		

TARGET STATES OF RECOVERY

Performance measure	Description of usability after expected event
	BUILDINGS LIFELINES
	Category A: Safe and operational
	Category B: 100% restored Safe and usable in 4 hours during repairs
	Category C: 100% restored Safe and usable in 4 months after moderate repairs
	Category D: 100% restored Safe and usable in 3 years after major repairs
	Expected current status

Note: Categories A–D are defined on page 10.



Target States of Recovery for San Francisco's Building & Infrastructure

Phase III

TARGET STATES OF RECOVERY FOR SAN FRANCISCO'S BUILDINGS AND INFRASTRUCTURE

INFRASTRUCTURE CLUSTER FACILITIES	Event occurs	Phase 1 Hours			Phase 2 Days		Phase 3 Months		
		4	24	72	30	60	4	36	36+
COMMUNITY RECOVERY									
All residences repaired, replaced or relocated									×
95% neighborhood retail businesses open								×	
50% offices and workplaces open									×
Non-emergency city service facilities								×	
All businesses open									×
100% utilities									×
100% roads and highways									×
100% travel									×

Source: SPUR analysis

TARGET STATES OF RECOVERY

Performance measure	Description of usability after expected event	
	BUILDINGS	LIFELINES
	Category A: Safe and operational	
	Category B: Safe and usable during repairs	100% restored in 4 hours
	Category C: Safe and usable after moderate repairs	100% restored in 4 months
	Category D: Safe and usable after major repairs	100% restored in 3 years
	Expected current status	

Note: Categories A–D are defined on page 10.



Need New Design Codes and Standards

Requires a Transparent Approach

- **Next generation hazard definitions**
 - Expected earthquake for building resilience
 - Extreme earthquake for lifelines and building safety
- **New Vocabulary to describe damage in terms of response and recovery**
 - Describe in terms of safety and usability
 - Required for Buildings and lifelines
- **Performance Objectives to support resilience**
 - Add an intermediate “shelter-in-place” goal
 - Add lifeline system restoration goals





Questions?